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ABSTRACT

A graduate academic program in medical information science has been established at the University of California, San Francisco, for the education of scientists capable of performing research and development in information technology in the health care setting. This interdisciplinary program, leading to a Doctor of Philosophy degree, consists of an introductory series of courses in medical information, computer sciences, medical systems analysis, and measurement and evaluation, followed by advanced course work and dissertation research. Students are conducting dissertation research on a variety of problems arising from the proliferation of medical knowledge and the increased need for management of medical data. Faculty and student research is supported by a Laboratory of Medical Information Science, an on-line computer facility which acts as an institutional focus for work on medical information systems. Work in progress includes systems for pharmacy management and utilization review, studies on human factors in information systems, and analysis of clinical decision-making. (Author)

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# A GRADUATE ACADEMIC PROGRAM IN MEDICAL INFORMATION SCIENCE

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# A GRADUATE ACADEMIC PROGRAM IN MEDICAL INFORMATION SCIENCE


## Abstract

A graduate academic program in medical information science has been established at the University of California, San Francisco, for the education of scientists capable of performing research and development in information technology in the health care setting. This interdisciplinary program, leading to a Doctor of Philosophy degree, consists of an introductory series of courses in medical information, computer sciences, medical systems analysis, and measurement and evaluation, followed by advanced course work and dissertation research.

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# A GRADUATE ACADEMIC PROGRAM IN MEDICAL INFORMATION SCIENCE

## I troduction

The practice of medicine and the operation of health care systems increasingly focuses on the acquisition, analysis and dissemination of information. Advancing medical technology and evolving socio-medical systems continously increase the volume and scope of the medical data base. Properly used, this information can greatly improve the quality and efficiency of health care. Unfortunately, our ability to generate meaningful medical data far surpasses our sophistication in the management, analysis, and utilization of this data. As a result, health care agencies are waging a desperate battle to withstand a literal deluge of clinical information.

The content of the field of medical information science and the need for its advancement thus become apparent. There is an immediate need for technological solutions because of the proliferation of medical knowledge, the multiplicity of special patient services and techniques, and the rising expectations for improved medical care. Beyond the foregoing issues, information science may be expected to change the very quality of medicine.

One of the most exciting prospects of information technology as applied to medicine lies in the detection of cause-effect relationships when the intervening time interval is lengthy--months or years. Such is almost certainly the case with many degenerative and neoplastic diseases, and increased understanding of them will require vastly improved means of acquiring and storing medical data, and associative processing. A problem of comparable importance, but different in nature, is the monitoring of the quality of medical services, and appropriateness of use of scarce resources. To accomplish these functions, in a real-time mode, is a high priority target if our health care delivery systems are to meet the current social challenge. Finally, the system of information flow within a health service imposes a *de facto* structuring of the facility, which may or may not resemble the intended organization.

It is thus essential that health system management science both advance and closely coordinate with the research and development of information science.

Because of the information explosion of the last decade, the need for adequately trained information scientists is severe. The sophistication and complexity of the information processes in medicine are fully as great as those in any human endeavor. Furthermore, practical experience has revealed the need for medical information specialists to be intimately familiar with the concepts and methodology of medicine, and with the structure of the health services system. The shortage of general information scientists and the special demands of medicine and health care, emphasize the need for a particular discipline - medical information science.

Development of the Academic Program at the University of California, San Francisco

The recognition of the need for an academic program in medical information science, and the opportunity to develop one, occurred on our campus at approximately the same time. The Office of Medical Information Systems was established in October 1969 and charged with the responsibility of developing hospital information systems for the University Hospitals and Clinics, and of developing academic programs as appropriate. Despite the obvious needs for familiarizing physicians with computer technology or for teaching medical students improved means of record-keeping and of data management, we concluded that the most urgent need was for a formal academic program at the Ph.D. level. There was both a need to define the field and to define the specific problems. An academic field is best defined by the work of practitioners in the field rather than in the abstract, so one needs first to have practitioners. An acceptable definition of the problems is essential in counteracting past industry efforts to sell solutions to problems not yet defined. A proper definition of an interdisciplinary academic field, and the classification of problems in that field, are matters of considerable complexity, and warrant the most serious of efforts. Through the support of the University of California, the National Library of Medicine, and the Commonwealth Fund, such a graduate academic program became possible and was developed during the period 1969-1972, and begun in September, 1972.

Program concepts -- the interdisciplinary nature of the field.

Research in medical information science requires a theoretical and practical knowledge of several disciplines. It is the goal of the academic curriculum, as presented below, to give this necessary interdisciplinary training. Although the various fields are fairly evident, it nevertheless took considerable time, for example, for the value of formal financial and accounting instruction to become evident, and to be incorporated into our program. The economic trade-offs involved in medical systems are becoming increasingly important although they were largely ignored until a few years ago. In addition, the contribution which can be made by other fields such as linguistics remains underemphasized.

For the very reason that one cannot predict in advance the utility of a given technique in performing research, students are encouraged to follow their own inclinations where ever practicable and the program has been maintained as flexible as possible. This flexibility has been very valuable in allowing students to pursue their individual interests.

Core Curriculum

The first year in the graduate program in Medical Information Science, consists of a Core Curriculum which all students follow and which provides a thorough introduction and background for advanced course work and research. The specific courses include medical systems, computer science, operations research and systems analysis, and measurement and evaluation (see Figure 1).

The courses in medical systems are designed to introduce the students to the medical environment and the nature of medical information. Students learn the role of various health care professionals, the functions of various medical and health organizations, the nature of information flow in the medical community, and the overall operation of the health care delivery system. Special emphasis is given to the sources and types of medical data, the evaluation and use of medical data,

| | MEDICAL INFORMATION | COMPUTER SCIENCES | MEDICAL SYSTEMS ANALYSIS | MEASUREMENT AND EVALUATION |
|---|---|---|---|---|
| Fall | The Medical Environment (2) | Programming Concepts and Information Structures (4)<br><br>The Computing Environment (1) | Administration and Evaluation of Health Care Systems (3) | Introduction to Operations Research (3) |
| Winter | The Nature of Medical Information (2) | Computer and Communication Systems I (4) | Systems Analysis of Medical Care (3)<br><br>Practicum (1) | Compumetrics: Statistical Data Analysis (3) |
| Spring | | Computer and Communication Systems II (4)<br><br>Computer Systems in the Health Setting (2) | Design of Medical Information Systems (3)<br><br>Practicum (1) | Compumetrics: Probability Modeling and Simulation (3) |

Figure 1. The Core Curriculum (See Appendix for course description) with number of credits for each course.

and various approaches to medical record keeping. No formal medical training is given, although a course in human biology is a highly desirable prerequisite for students without any previous experience in a life science.

The computer science courses deal primarily with the nature and use of data structures, programming languages, operating systems, and techniques in designing large systems. An attempt is made to have the students understand the trade-offs involved in selecting various approaches to system design. Emphasis is given to on-line, multi-programmed computer systems. Students use the laboratory facilities (see below) for problem solving.

The operations research and system analysis area includes topics in linear programming technique as well as the application of these and other techniques to the design of medical information systems. Some material on management finance and accounting is included so that students become able to make cost-benefit and cost-effectiveness analysis of systems.

The courses in the measurement and evaluation area include courses in statistics and in simulation. Many of the failures in the design of medical information systems have occurred because of inaccurate predictions of system load, response time, or cost. These courses are designed to give the student the tools to be able to predict and evaluate the performance of such systems.

A listing of courses in the core curriculum, along with their catalogue description may be found in the appendix. Following completion of the courses in the core curriculum, the student is expected to do advanced course work in one or more of these four basic areas, or in an outside area such as linguistics which has direct application to medical information science. Students are free to take virtually any course given at the University of California San Francisco or Berkeley campuses or to take directed reading under their graduate advisor.

Anticipated Job Opportunities

Although the major goal of the program is the training of Ph.D. candidates, in the expectation that they will fullfil traditional roles in research and teaching, and for administrative positions in industry and government, there appear to be many other opportunities for a high quality graduate of this type. It is expected that from a third to a half of our students may choose to complete their training after receipt of the Masters Degree. We believe that a new role will open up in the near future for individuals trained in Medical Information Science, viz., as members of a hospital administration. Although the fraction of hospitals in the United States with significant computer installations is still a small one, the majority of hospitals probably now have their billing and accounting done by computer methods, most probably through a service bureau. In addition, laboratory information systems are now being provided by a growing number of commercial vendors and are achieving increasing acceptance in hospitals, and other hospital subsystems seem sure to follow. As hospitals begin to deal with computer-based technology on an increasing scale, it will become necessary for hospital administrations to have expertise in planning, operating, maintaining, and otherwise managing such facilities.

Graduate Student Research

In this program as elsewhere in the University, the essence of graduate education which leads to the doctoral degree is the conduct of original research. Because of the very close relationship between the academic program and the ongoing systems development on our campus, the students will have an excellent opportunity to choose and affiliate with meaningful doctoral research. The on-campus facilities include a total of 550 hospital beds distributed between two acute hospitals, a psychiatric institute, and out patient clinics in all medical and surgical specialties. Furthermore the University participates in a number of community and experimental health delivery projects. The faculty of the graduate program include in addition to full-

time faculty, members of other health care organizations within the San Francisco Bay Area, representing still other opportunities for graduate student research. Finally, some students may elect to perform specialized research at the Berkeley campus at the University of California, in particular fields in which they have developed a specialized interest.

Laboratory of Medical Information Science

One of the central themes of the Graduate Program is the combination of academic training with practical experience in the field of medical information systems. This practical experience is developed in two different ways within the Graduate Program:

1) through a Practicum (or, brief work experience) in which students are individually assigned to various departments within the University of California Hospitals and Clinics for a period of one quarter;
2) through Laboratory programs which provide a framework in which studies on basic problems of medical information systems can be investigated.

The Practicum is a required part of the core curriculum within the Graduate Program. The Medical Center setting provides an excellent opportunity for students to examine real problems that exist in the administration and operation of the institution and to propose solutions. The students have the opportunity to deal not only with the technical matters of introducing and utilizing information systems, but also with the personal, social, and economic problems which are intimately related. A key goal of the Practicum is to teach the students to analyze the total impact of a medical information system on the delivery of health care.

The goal of the Laboratory is to act as an institutional focus for research in medical information science and hence to provide a facility for graduate student and faculty research. The emphasis of the Laboratory is, so far as practical, on basic research, the results of which will be generally applicable, rather than on

specific systems for the institution. Work is generally directed to those problems which currently impede the effective utilization of computer technology in our health care systems, including the lack of suitable man-machine interfaces, the lack of suitable programming languages for use by non-computer scientists, the lack of cost-effective hardware systems which can be used by smaller hospitals, and the lack of low-cost mass storage systems.

The facility itself includes a medium-scale computer with a complete set of peripherals which is available for hands-on usage by faculty and graduate students. This computer was specifically chosen because of its:

1) ability to support multiple on-line users through time-sharing or multiprogramming,
2) ability to support a number of remote terminals,
3) substantial vendor software for the machine,
4) availability of source code for all vendor software, in order to allow modification and analysis,
5) easy physical operation for hands-on use,
6) simple interfaces to peripheral equipment, and
7) vendor's willingness to establish an ongoing working relationship.

The computer acquired was the Modular Computer Systems MODCOMP II (to be upgraded to a MODCOMP IV in Summer 1974) with 64K of 16-bit words and 5 million bytes of secondary disk storage. The Laboratory also has a small electronics workshop in which interface systems can be prepared, equipment can be modified, etc. A small, but growing, reading collection, consisting of books and journals, is also a part of the Laboratory.

Work is beginning on a number of projects within the Laboratory. These projects fall within the broad areas of system acceptability, decision-making, and pattern recognition. Specific problems which are being studied include:

1) the automation of outpatient medical records;
2) development and evaluation of man-machine interfaces for health professionals

3) development of a "programming environment" for the implementation of medical information systems, including text editors, programming languages, operating systems, and debugging facilities
4) decision-making using clinical laboratory variables
5) data reduction for utilization review

In addition to these problems, pilot studies are being made for several hospital subsystems, with work often based on information gained from the Practicum.

Graduate students are introduced to the Laboratory during the first quarter of the core curriculum and are encouraged to become thoroughly familiar with its facilities. It is expected that the Laboratory can serve to support a series of student research projects carried out under the direction of faculty members who represent a number of different disciplines and thus help to overcome the traditional compartmentalization which often characterizes institutional research. Accordingly, the Laboratory has been given a sense of direction which cuts across conventional academic boundaries. In this way, it will be possible to bring together components of the solutions to problems in medical information systems from the many sectors within the program, including computer technology, operations research, systems analysis, and health services research.

## Progress of the Graduate Program

The first students entered the Graduate Program in Fall 1972. There were eight students during the 1972-1973 academic year and a total of fifteen during the 1973-1974 academic year. An extensive recruiting effort has been conducted for the 1974-1975 year and approximately ten new students will be admitted to the program. The first M.S. degree was granted in June 1973 and three more were granted in the 1973-1974 academic year. The first Ph.D. degree will be granted in late 1974.

During that time, the faculty has grown from an original Teaching Group with part-time participation from a number of persons to include two full-time faculty

members, one in computer sciences and one in operations research, along with several lecturers from outside the University who teach specific courses.

The experience of the first two years of the academic program has resulted in modifications to some of our courses and a reordering of the courses within the core curriculum. As noted, the need for students to acquire some understanding of accounting and finance at an early stage became apparent. Accordingly, this course was moved to the first quarter of the academic year, while the measurement and evaluation courses were deferred. Advanced seminars for students who have completed the core curriculum are now available.

The development of a joint degree program in medical information science with the nearby Berkeley campus of the University of California is being completed. The result of this effort will be to bring the extensive resources of the Berkeley campus to the support of our program, particularly in the second year, by facilitating students participation in advanced courses there as well as in San Francisco. Several members of the Teaching Group in San Francisco hold part-time faculty appointments at Berkeley as well. However, the first year course work and the core curriculum will continue to be located on the San Francisco campus, which alone provides the necessary medical institutions.

The diversity of student backgrounds continues to contribute importantly to the Program. In addition to students with advanced training in mathematics and computer sciences, the present group of students includes a pharmacist, a physician, and several students with considerable practical experience in the medical information field. Two of the students are working on information systems for utilization review. Another has developed a pharmacy management system for the University of California Hospital. These solutions to the real problems being addressed by the students can improve the quality of patient care, while at the same time meeting the standards for graduate degrees.

Conclusion

In summary, many of the administrative tasks involved in the development of

the program have now been completed, and it is becoming possible to make more rapid progress in training students. By Fall 1974 slightly more than twenty students will be enrolled, with about half in the Doctoral program and half in the Masters degree program. A student group of from twenty to twenty-five students in all years seems to be an ideal number for the Program. Within the next two to three years, it should become possible to see tangible results of this training, as students complete their work and obtain professional employment.

Acknowledgements

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It is not practicable to acknowledge the contributions of all those who have participated in the establishment of this program, but the efforts of Professors John Starkweather, Robert Elashoff, and Dr. Ronald Henley of the University of California, San Francisco, have been particularly important.

## APPENDIX

### Medical Information Science Core Curriculum Course Descriptions

Medical Information

The Medical Environment (MIS-201)

Survey settings within which medical & health care delivered. Includes private practitioner, group practitioner, clinics, poly-clinics, neighborhood health centers, community hospitals, medical centers. Functional attributes considered from viewpoint of history, economics, social and political evolution. Purpose -- give background for students without previous contact with health care systems, concerning processes, functions, constraints of health care delivery.

The Nature of Medical Information (MIS-202)

Medical information from the viewpoint of several taxonomies: general medical knowledge versus specific patient data, medical information expressible in numeric, graphical or natural language means. Particular emphasis on the distinguishing of algorithmic from nonalgorithmic processing of medical data.

Computer Sciences

Programming Concepts and Information Structures (MIS-190)

Representation of programs and data in the digital computer. Information structures used for data representation. Non-numeric information handling techniques, including list processing and string processing. Implementation of data structures in existing programming languages and computer systems.

The Computing Environment (MIS-192)

A survey of present and future computing facilities available in the health care and research setting. The course will involve guest speakers with specific hardware and software systems available to students, faculty, and practitioners, particularly those available in the local setting.

Computer Systems in the Health Setting (MIS-193)

An exploration of existing systems or those under development which use computers to assist in health care, health research or instruction of health

professionals. Invited speakers and visits to specific installations will be a part of the course.

Computer and Communications Systems I (MIS-210A)

Introduction to computer system organization. Interface between system components. Assemblers and loaders. Methods of translating programming languages.

Computer and Communications Systems II (MIS-210B)

Operating systems concepts. Scheduling algorithms. Memory management. File system organization and structure. Integration of hardware, software and data. Communication system organization and structure. Data base structure. Emphasis on design of on-line systems.

Medical Systems Analysis

Practicum in Medical Information Systems (MIS 203 and 204)

Students will be working with laboratories and the hospital staff to gain experience on information and computing problems.

Administration and Evaluation of Health Care Systems (MIS-205)

Concepts, principles, definitions, and processes of management and financial accounting with particular emphasis upon hospitals and other health care systems. The theory and practice of management and organization and of accounting, cost analysis and budget control, will be developed with an emphasis on practical applications.

Systems Analysis of Medical Care (MIS-220)

Systems problems in medical facilities are analyzed for applicability of statistical methods and operations research. Emphasis on formulating problems so that quantitative techniques can be applied, and on identifying problems amenable to solution using quantitative technique. Selected techniques are introduced.

Design of Medical Information Systems (MIS-225)

The design of previous medical information systems will be examined. Successful components of these systems will be studied in depth, with respect to cost, performance and acceptability. Proposals for new systems will be presented and reviewed.

Measurement and Evaluation

Introduction to Operations Research (MIS-191)

The philosophy of operations research and its approach to problem solving. Analysis of the theoretical decision model. Probabilities, statistics and decision theory. Information for decision making and its cost. Selected optimization and search models applied to health care.

Compumetrics: Probability Modelling and Simulation (MIS-230B)

Role of simulation, design and interpretation of benchmarks, analysis of outputs from hardware-software monitors, the development of suitable analytic models. Problems of demand structure also will be studied as well as qualitative analysis of systems structure.

Compumetrics: Statistical Data Analysis (MIS-230A)

Measurement problems in computer systems behavior and performance. Topics include experimental design, analysis of variance, regression and forecasting.